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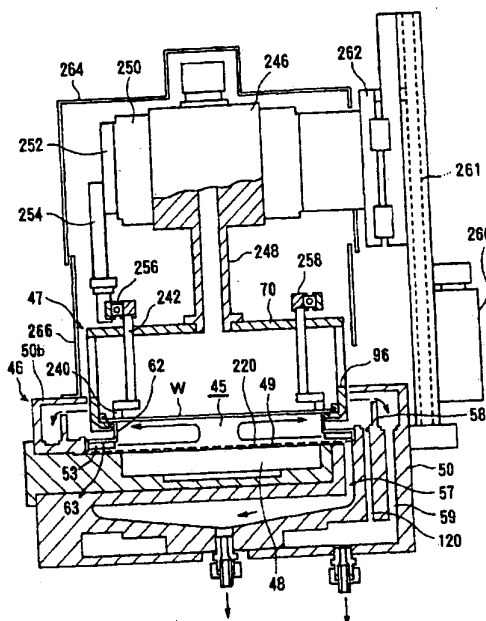
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## (54) Plating apparatus and plating liquid removing method

(57) A plating apparatus and a plating liquid removing method removes a plating liquid remaining on the substrate-contacting portion or its vicinity of a substrate holding member. The plating apparatus comprising a head having a rotatable housing provided with a sub-

strate holding member for holding a substrate, a plating process container, disposed below said head, for holding a plating liquid therein, and a plating liquid removing mechanism for removing a plating liquid remaining on a substrate-contacting portion or its vicinity at an inner circumferential edge of said substrate holding member.

FIG. 4



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## Description

## BACKGROUND OF THE INVENTION

## Field of the Invention:

[0001] The present invention relates to a plating apparatus and a plating liquid removing method, and more particularly to a plating apparatus useful for filling a metal such as copper into recesses for interconnects formed on a semiconductor substrate and a method for removing a plating liquid remaining on the substrate-contacting portion or its vicinity of a substrate holding member for use in the plating apparatus.

## Description of the Related Art:

[0002] Generally, aluminum or aluminum alloy has been used as a material for forming interconnect circuits on a surface of a semiconductor substrate. The higher integrated density on the semiconductor substrate requires that a material having a higher electric conductivity should be used for interconnect circuits. Therefore, there has been proposed a method comprising plating a surface of a substrate to fill interconnect patterns formed in the substrate with copper or copper alloy.

[0003] Various methods such as chemical vapor deposition (CVD) process, sputtering process, and the like have been used to fill interconnect patterns formed in a substrate with copper or copper alloy. However, when a metallic layer on a substrate is formed of copper or copper alloy, i.e., when copper interconnects are formed on the substrate, the CVD process requires high cost, and, if an aspect ratio is high (i.e., the depth of the pattern is larger than the width), then it is difficult to fill the interconnect patterns with copper or copper alloy in the sputtering process. Therefore, the aforementioned plating method is most effective to fill interconnect patterns formed in a substrate with copper or copper alloy.

[0004] There are various methods for plating a surface of a semiconductor substrate with copper. For example, in a cup-type plating method, a dip-type plating method, or the like, a plating tank always holds a plating liquid, and a substrate is dipped into the plating liquid. In another plating method, a plating tank holds a plating liquid only when a substrate is fed into the plating container. Further, in an electrolytic plating method, an electric potential difference is applied to plate a substrate. On the other hand, in an electroless plating method, an electric potential difference is not applied.

[0005] In cup-type plating apparatuses, a substrate is held by a substrate holding member with the peripheral edge and the back surface of the substrate being sealed, and plating is performed by contacting the exposed front surface of the substrate with a plating liquid. After the plating treatment, the plating liquid is likely to remain on the substrate-contacting portion or its vicinity of the substrate holding member. The remaining plating

liquid, when dried, can produce undesired particles. Moreover, the remaining plating liquid can adhere to the next substrate to be plated, leading to an insufficient plating of the substrate.

[0006] A method has been developed for removing such a plating liquid remaining on the substrate-contacting portion or its vicinity of a substrate holding member. According to this method, a plating liquid removing device, having an absorbent for absorbing a plating liquid or a sucking tool for sucking a plating liquid, is allowed to move in a circumferential direction along the substrate-contacting portion or its vicinity of a substrate holding member so as to remove by absorption or suction the remaining plating liquid on the substrate-contacting portion or its vicinity.

[0007] The above conventional plating apparatuses that carry out the method, however, have the following drawbacks: The conventional apparatuses is so designed that the substrate holding member is fixed stationarily while the plating liquid removing device is allowed to rotate. This makes it impossible to conduct dewatering (spin-drying) of the plating liquid remaining on the substrate-contacting portion or its vicinity of the substrate holding member. Since a large quantity of plating liquid thus remains, it is necessary to conduct the plating liquid removing operation for every plating treatment. Moreover, each plating liquid removing operation needs a considerably long time. Furthermore, the removal of the large quantity of plating liquid leads to consumption of an increased amount of plating liquid, resulting in an increased production cost.

## SUMMARY OF THE INVENTION

[0008] The present invention has been made in view of the above drawbacks in the related art. It is therefore an object of the present invention to provide a plating apparatus and a plating liquid removing method which can easily and quickly remove the plating liquid remaining on the substrate-contacting portion or its vicinity of a substrate holding member, and which enables a simplified apparatus structure that requires a smaller space for installation.

[0009] According to a first aspect of the present invention, there is provided a plating apparatus, comprising: a head having a rotatable housing provided with a substrate holding member for holding a substrate; a plating process container, disposed below the head, for holding a plating liquid therein; and a plating liquid removing mechanism for removing a plating liquid remaining on a substrate-contacting portion or its vicinity at an inner circumferential edge of the substrate holding member.

[0010] The above apparatus can effectively remove the plating liquid remaining on the substrate-contacting portion or its vicinity at the inner circumferential edge of the substrate holding member, forcibly. This can avoid the problem of particle generation that would be caused by an unremoved plating liquid when it is dried. A pos-

sible dissolution of the seed layer of the next substrate by the unremoved plating liquid can also be avoided. Further, the above apparatus, which allows the substrate holding member to rotate, makes it possible to remove plating liquid and, in addition, eliminates the need to rotate the plating liquid removing mechanism.

[0011] In a preferred aspect of this invention, the plating liquid removing mechanism has a plating liquid suction nozzle which can move close to the substrate-contacting portion at the inner circumferential edge of the substrate holding member and sucks the plating liquid remaining on the substrate-contacting portion or its vicinity.

[0012] The plating liquid suction nozzle may have an arc shape extending along the substrate-contacting portion of the substrate holding member, and may be designed to be movable in vertical and horizontal directions. The use of such a suction nozzle can carry out the removal of the remaining plating liquid on the substrate-contacting portion or its vicinity efficiently in a short time.

[0013] In a preferred aspect of this invention, the plating liquid removing mechanism also has a cleaning liquid injection nozzle which can move close to the substrate-contacting portion at the inner circumferential edge of the substrate holding member and ejects a cleaning liquid toward the substrate-contacting portion or its vicinity.

[0014] With this construction, the cleaning liquid injection nozzle ejects a cleaning liquid, e.g. pure water, toward the substrate-contacting portion or its vicinity at the inner circumferential edge of the substrate holding member, thereby cleaning the substrate-contacting portion or its vicinity. Further, the plating liquid remaining on the substrate-contacting portion or its vicinity is suction-removed, together with the cleaning liquid, by the plating liquid suction nozzle. This can prevent the plating liquid from remaining in the inside of the plating liquid suction nozzle and clogging the nozzle when the liquid is dried.

[0015] According to a second aspect of this invention, there is provided a plating apparatus, comprising: a head having a rotatable housing provided with a substrate holding member for holding a substrate; and a plating process container, disposed below the head, for holding a plating liquid therein; wherein the substrate holding member is provided with a sealing member for sealing an outer peripheral edge of the substrate, the sealing member being made of a highly water-repellent material

[0016] With this construction, the sealing member, which is to be contacted with the substrate, is made of a highly water-repellent material. This can reduce the amount of the plating liquid that remains on the surface of the sealing member. Silicone rubbers may be used as the highly water-repellent material. Ordinary silicone rubbers, however, have a poor durability. In order to ensure a sufficiently high tensile strength, it is preferred to use a high-tearing strength silicone rubber having en-

hanced tensile strength. The use of the specific rubber provides a sealing member having both a good sealing property and a high durability.

[0017] According to a third aspect of this invention, there is provided a plating apparatus, comprising: a head having a rotatable housing provided with a substrate holding member for holding a substrate; a plating process container, disposed below the head, for holding a plating liquid therein; and a plating liquid removing mechanism for removing a plating liquid remaining on a substrate-contacting portion or its vicinity at an inner circumferential edge of the substrate holding member; wherein the substrate holding member is provided with a sealing member for sealing an outer peripheral edge of the substrate, the sealing member being made of a highly water-repellent material.

[0018] According to a forth aspect of this invention, there is provided a plating apparatus, comprising: a head having a rotatable housing provided with a substrate holding member for holding a substrate; and a plating process container, disposed below the head, for holding a plating liquid therein; wherein the substrate holding member is provided with a sealing member for sealing an outer peripheral edge of the substrate, the sealing member having a substrate-contacting portion which is in a shape of a spire, in cross section, with a flat top surface.

[0019] With this construction, the specific configuration of the sealing member at the substrate-contacting portion can enhance the rigidity of the substrate-contacting portion, and furthermore, can make the plating liquid remain on the inner side of the top flat surface, not allowing the plating liquid to flow to the outer side (electrical contact side). This is advantageous because the plating liquid, if flowed into the outer side, would not sufficiently be suction-removed and would still remain.

[0020] According to a fifth aspect of this invention, there is provided a plating apparatus, comprising: a head having a rotatable housing provided with a substrate holding member for holding a substrate; a plating process container, disposed below the head, for holding a plating liquid therein; and a plating liquid removing mechanism for removing a plating liquid remaining on a substrate-contacting portion or its vicinity at an inner circumferential edge of the substrate holding member; wherein the substrate holding member is provided with a sealing member for sealing an outer peripheral edge of the substrate, the sealing member having a substrate-contacting portion which is in a shape of a spire, in cross section, with a flat top surface.

[0021] According to a sixth aspect of this invention, there is provided a method for removing a plating liquid remaining on a substrate-contacting portion or its vicinity at an inner circumferential edge of a substrate holding member for holding a substrate, comprising: rotating the substrate holding member to remove the plating liquid from the substrate holding member; and sucking the plating liquid remaining on the substrate-contacting por-

tion or its vicinity of the substrate holding member, while the substrate holding member is rotated.

[0022] According to a seventh aspect of this invention, there is provided a plating method, comprising: plating a substrate held by a substrate holding member of a rotatable housing; rotating the housing to remove a plating liquid remaining on the substrate and the substrate holding member; taking the substrate out of the housing; and sucking the plating liquid remaining on a substrate-contacting portion or its vicinity at the inner circumferential edge of the substrate holding member, while the substrate holding member is rotated.

[0023] According to a eighth aspect of this invention, there is provided a plating apparatus comprising: a head having a rotatable housing provided with a substrate holding member for holding a substrate; a plating process container, disposed below the head section, for holding a plating liquid therein; and a plating liquid removing mechanism for removing a plating liquid remaining on a substrate-contacting portion or its vicinity at the inner circumferential edge of the substrate holding member; wherein the plating liquid removing mechanism has a plating liquid sucking member which is allowed to be introduced into the housing through an opening of the opening and to move near to the substrate holding member, the plating liquid sucking member, when located so as to face the substrate holding member, sucks and removes the plating liquid remaining on the substrate-contacting portion or its vicinity at the inner circumferential edge of the substrate holding member, while the substrate holding member is rotated.

[0024] According to a ninth aspect of this invention, there is provided a plating method, comprising: plating a substrate held by a substrate holding member of a rotatable housing; rotating the housing to remove a plating liquid remaining on the substrate and the substrate holding member; taking the substrate out of the housing through an opening of the opening; causing a plating liquid-sucking member of a plating liquid removing mechanism to face the substrate holding member by introducing the plating liquid removing mechanism into the housing through the opening; and removing the plating liquid remaining on the substrate-contacting portion or its vicinity at an inner circumferential edge of a substrate holding member in such a state that the plating liquid-sucking member faces closely the substrate holding member, while the substrate holding member is rotated.

[0025] The above and other objects, features, and advantages of the present invention will be apparent from the following description when taken in conjunction with the accompanying drawings which illustrates preferred embodiments of the present invention by way of example.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0026]

FIGS. 1A through 1C are cross-sectional views showing an example of a plating process utilizing the plating apparatus according to the present invention;

FIG. 2 is a plan view showing a layout of a plating apparatus according to a first embodiment of the present invention;

FIG. 3 is an explanatory view showing an air current in the plating apparatus shown in FIG. 2;

FIG. 4 is a cross-sectional view showing a whole structure of a plating unit at the time of plating process in a plating apparatus shown in FIG. 2;

FIG. 5 is a schematic diagram showing a flow of a plating liquid in a plating apparatus shown in FIG. 2;

FIG. 6 is a cross-sectional view showing a whole structure of the plating unit at the time of non-plating process (at the time of transfer of a substrate);

FIG. 7 is a cross-sectional view showing a whole structure of the plating unit at the time of maintenance;

FIG. 8 is a cross-sectional view explanatory of a relationship among a housing, a pressing ring, and a substrate at the time of transfer of a substrate;

FIG. 9 is an enlarged view showing a part of FIG. 8;

FIGS. 10A through 10D are schematic views explanatory of the flow of a plating liquid at the time of plating process and at the time of non-plating process;

FIG. 11 is an enlarged cross-sectional view showing a centering mechanism in the plating unit;

FIG. 12 is a cross-sectional view showing a feeding contact (probe) in the plating unit;

FIG. 13 is a plan view showing a plating liquid removing mechanism in the plating unit;

FIG. 14 is a front view showing the plating liquid removing mechanism shown in FIG. 13;

FIG. 15 is a perspective view of the main portion of a plating liquid removing mechanism.

FIGS. 16A through 16C are enlarged cross-sectional views of the main portion of a sealing member;

FIGS. 17A and 17B are diagrams illustrating problems encountered upon using a conventional sealing member; and

FIG. 18 is a graph showing the change in contact angle for fluorine rubber- and silicone rubber-sealing members before and after 762.65-hour dipping in plating liquid.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] A plating apparatus according to embodiments of the present invention will be described below with reference to the accompanying drawings.

[0028] A plating apparatus according to embodiments of the present invention is used for plating a surface of a semiconductor substrate with copper, for thereby manufacturing semiconductor devices on which interconnects having a copper layer are formed. This plating process will be described below with reference to FIGS. 1A through 1C.

[0029] As shown in FIG. 1A, an insulating film 2 of  $\text{SiO}_2$  is deposited over a conductive layer 1a on a semiconductor base 1 having semiconductor devices, and then a contact hole 3 and a trench 4 for an interconnect are formed by lithography and etching technology. A barrier layer 5 made of TiN or the like is formed on the insulating film 2, and a copper seed layer 7 as an electric supply layer for an electrolytic plating is formed on the barrier layer 5 by sputtering or the like.

[0030] Subsequently, as shown in FIG. 1B, a surface of a substrate W is plated with copper. Hence, the contact hole 3 and the trench 4 on the semiconductor base 1 are filled with copper, and a copper layer 6 is formed on the insulating film 2. Thereafter, the copper layer 6 on the insulating film 2 is removed by chemical mechanical polishing (CMP) so that the surface of the copper layer 6 filled in the contact hole 3 and the trench 4 is made substantially even with the surface of the insulating film 2. Thus, as shown in FIG. 1C, an interconnect comprising the copper layer 6 is formed.

[0031] A plating apparatus for electrolytically plating a semiconductor substrate W according to a first embodiment of the present invention will be described below with reference to FIG. 2. As shown in FIG. 2, the plating apparatus is disposed in a rectangular facility 10, and is constituted so as to plate a semiconductor substrate with copper continuously. The facility 10 has a partition wall 11 for dividing the facility 10 into a plating section 12 and a clean section 13. Air can individually be supplied into and exhausted from each of the plating section 12 and the clean section 13. The partition wall 11 has a shutter (not shown) capable of opening and closing. The pressure of the clean section 13 is lower than the atmospheric pressure and higher than the pressure of the plating section 12. This can prevent the air in the clean section 13 from flowing out of the facility 10 and can prevent the air in the plating section 12 from flowing into the clean section 13.

[0032] In the clean section 13, there are provided two cassette stages 15 for placing a substrate cassette thereon, and two cleaning and drying units 16 for cleaning (rinsing) a plated substrate with pure water and drying. Further, a rotatable fixed-type first transfer device (tetraaxial robot) 17 for transferring a substrate is provided in the clean section 13. For example, the cleaning and drying unit 16 has cleaning liquid supply nozzles for supplying ultrapure water to both surfaces of a substrate, and spins the substrate at a high speed to de-water and dry the substrate.

[0033] On the other hand, in the plating section 12, there are provided two pre-treatment units 21 for pre-

treating a surface of a substrate for plating, and inverting the pretreated substrate by an inverter 20, four plating units 22 for plating a surface of a substrate with copper in such a state that the front surface of the substrate faces downwardly, and two first substrate stages 23a, 23b for holding a substrate placed thereon. Further, a rotatable mobile-type second transfer device (tetraaxial robot) 24 for transferring a substrate is provided in the plating section 12.

[0034] In the clean section 13, there are provided two chemical liquid cleaning units 25 for cleaning a plated substrate with chemical liquid, and second substrate stages 26a, 26b disposed between the chemical liquid cleaning units 25 and the cleaning and drying units 16. A rotatable fixed-type third transfer device (tetraaxial robot) 27 for transferring a substrate is provided between the two chemical liquid cleaning units 25.

[0035] One of the first substrate stage 23b and the second substrate stage 26b are constituted so as to clean the substrate with water. Each of the first substrate stage 23b and the second substrate stage 26b has an inverter 20 for inverting a substrate.

[0036] Thus, the first transfer device 17 transfers a substrate between the substrate cassettes placed on the cassette stages 15, the cleaning and drying units 16, and the second substrate stages 26a, 26b. The second transfer device 24 transfers a substrate between the first substrate stages 23a, 23b, the pre-treatment units 21, and the plating units 22. The third transfer device 27 transfers a substrate between the first substrate stages 23a, 23b, the chemical liquid cleaning units 25, and the second substrate stages 26a, 26b.

[0037] The transfer device 17 has two recess-type hands, respectively for supporting a peripheral edge of a substrate by a recess. The upper hand is used for handling a dry substrate and the lower hand is used for handling a wet substrate. Each of the transfer devices 24 and 27 has two recess-type hands, which are used for handling a wet substrate. The hands of the transfer devices are not limited to those types described above.

[0038] In the present embodiment, the plating apparatus comprises the chemical liquid cleaning units 25 for cleaning a surface of a substrate with chemical liquid such as dilute hydrofluoric acid or hydrogen peroxide. If it is not necessary to clean a plated substrate with chemical liquid, the chemical liquid cleaning units 25 are not required. In this case, the first transfer device 17 transfers a substrate between the substrate cassettes placed on the cassette stages 15, the cleaning and drying units 16, and the first substrate stages 23a, 23b to thus dispense with the third transfer device 27 and the second substrate stages 26a, 26b.

[0039] Next, the processing flow of the substrate in the plating apparatus according to the present embodiment will be described below. The substrates are accommodated in the substrate cassette in such a state that the front surface of the substrate (surface on which semiconductor devices are formed, i.e., surface to be

processed) faces upwardly, and the substrate cassette accommodating such substrates is placed on the cassette stage 15. The first transfer device 17 takes out a substrate from the substrate cassette, moves to the second substrate stage 26a, and places the substrate on the second substrate stage 26a. Then, the third transfer device 27 transfers the substrate from the second substrate stage 26a to the first substrate stage 23a. Thereafter, the second transfer device 24 receives the substrate from the first substrate stage 23a and transfers the substrate to the pre-treatment unit 21. After the pre-treatment of the substrate is completed in the pre-treatment unit 21, the substrate is inverted by the inverter 20 so that the front surface of the substrate faces downwardly, and then transferred to the second transfer device 24. The second transfer device 24 transfers the substrate to a head of the plating unit 22.

[0040] After the substrate is plated and liquid on the substrate is removed in the plating unit 22, the substrate is received by the second transfer device 24, which transfers the substrate to the first substrate stage 23b. The substrate is inverted by the inverter 20 provided at the first substrate stage 23b so that the front surface faces upwardly, and then transferred to the chemical liquid cleaning unit 25 by the third transfer device 27. In the chemical liquid cleaning unit 25, the substrate is cleaned with chemical liquid and rinsed with pure water, and then the liquid on the substrate is removed by spinning. Thereafter, the substrate is transferred to the second substrate stage 26b by the third transfer device 27. Next, the first transfer device 17 receives the substrate from the second substrate stage 26b, and transfers the substrate to the cleaning and drying unit 16. In the cleaning and drying unit 16, the substrate is rinsed with pure water and then spin-dried. The dried substrate is returned to the substrate cassette placed on the cassette stage 15 by the first transfer device 17.

[0041] FIG. 3 is a schematic view showing an air current in the facility 10. In the clean section 13, a fresh external air is introduced through a pipe 30 and pushed into the clean section 13 through a high-performance filter 31 by a fan. Hence, a down-flow clean air is supplied from a ceiling 32a to positions around the cleaning and drying units 16 and the chemical liquid cleaning units 25. A large part of the supplied clean air is returned from a floor 32b through a circulation pipe 33 to the ceiling 32a, and pushed again into the clean section 13 through the high-performance filter 31 by the fan, to thus circulate in the clean section 13. A part of the air is discharged from the cleaning and drying units 16 and the chemical cleaning liquid units 25 through a pipe 34 to the exterior, so that the pressure of the clean section 13 is set to be lower than the atmospheric pressure.

[0042] The plating section 12 having the pre-treatment units 21 and the plating units 22 therein is not a clean section (but a contamination zone). However, it is not acceptable to attach particles to the surface of the substrate. Therefore, in the plating section 12, a fresh

external air is introduced through a pipe 35, and a down-flow clean air is pushed into the plating section 12 from the ceiling 37a through a high-performance filter 36 by a fan, for thereby preventing particles from being attached to the surface of the substrate. However, if the whole flow rate of the down-flow clean air is supplied by only an external air supply and exhaust, then enormous air supply and exhaust are required. Therefore, the air is discharged through a pipe 38 to the exterior, and a large part of the down-flow is supplied by a circulating air through a circulation pipe 39 extended from a floor 37b, in such a state that the pressure of the plating section 12 is maintained to be lower than the pressure of the clean section 13.

[0043] Thus, the air returned to a ceiling 37a through the circulation pipe 39 is pushed again into the plating section 12 through the high-performance filter 36 by the fan. Hence, a clean air is supplied into the plating section 12 to thus circulate in the plating section 12. In this case, air containing chemical mist or gas emitted from the pre-treatment units 21, the plating units 22, the second transfer device 24, and a plating liquid regulating tank 40 is discharged through the pipe 38 to the exterior. Thus, the pressure of the plating section 12 is controlled so as to be lower than the pressure of the clean section 13.

[0044] FIG. 4 shows a main part of the plating unit 22. The plating unit 22 mainly comprises a plating process container 46 in the substantially cylindrical form for holding a plating liquid therein, and a head 47 disposed above the plating process container 46 for holding a substrate. In FIG. 4, the head 47 is located in a plating position in which a substrate W held by the head 47 is lowered.

[0045] The plating process container 46 is provided with a plating container 50 including a plating chamber 49, which is upwardly opened, for holding a plating liquid therein. An anode 48 made of residual-phosphorus copper, for example, is provided at the bottom of the plating chamber 49. The anode 48 is made of copper containing 0.03 % to 0.05 % phosphorus (residual-phosphorus copper), and hence a black film is formed on the upper surface of the anode 48 as plating proceeds. Such a black film can reduce generation of anode slime.

[0046] Plating solution supply nozzles 53 horizontally projecting toward the center of the plating chamber 49 are provided on the inner circumferential wall of the plating container 50 at equal intervals along the circumferential direction. Each of the plating liquid supply nozzles 53 is communicated with a plating liquid supply passage extended vertically through the interior of the plating container 50.

[0047] Further, according to this embodiment, a punch plate 220 having a large number of holes with a size of, for example, about 3 mm is disposed at a position above the anode 48 within the plating chamber 49. The punch plate 220 prevents a black film formed on the surface of the anode 48 from curling up by the plating

liquid 45 and consequently being flowed out.

[0048] The plating container 50 has first plating liquid discharge ports 57 for withdrawing the plating liquid 45 contained in the plating chamber 49 from the peripheral portion of the bottom of the plating chamber 49, and second plating liquid discharge ports 59 for discharging the plating liquid 45 which has overflowed a weir member 58 provided at the upper end of the plating container 50. Further, the plating container 50 has third plating liquid discharge ports 120 for discharging the plating liquid before overflowing the weir member 58. The plating liquid which has flowed through the second plating liquid discharge ports 59 and the third plating liquid discharge ports 120 join at the lower end of the plating container 50, and then is discharged from the plating container. Instead of providing the third plating liquid discharge ports 120, as shown in FIGS. 10A through 10D, the weir member 58 may have, in its lower part, openings 222 having a predetermined width at predetermined intervals so that the plating liquid 45 passes through the openings 222 and is then discharged to the second plating liquid discharge ports 59.

[0049] With this arrangement, when the amount of plating liquid supplied is large during plating, the plating liquid is discharged to the exterior through the third plating liquid discharge ports 120 or is passed through the openings 222 and discharged to the exterior through the second plating liquid discharge ports 59 and, in addition, as shown in FIG. 10A, the plating liquid overflows the weir member 58 is discharged to the exterior through the second plating liquid discharge ports 59. On the other hand, during plating, when the amount of plating liquid supplied is small, the plating liquid is discharged to the exterior through the third plating liquid discharge ports 120, or alternatively as shown in FIG. 10B, the plating liquid is passed through the openings 222 and discharged to the exterior through the second plating liquid discharge ports 59. In this manner, this construction can easily cope with the case where the amount of plating liquid supplied is large or small.

[0050] Further, as shown in FIG. 10D, through holes 224 for controlling the liquid level, which are located above the plating liquid supply nozzles 53, and communicate with the plating chamber 49 and the second plating liquid discharge ports 59, are provided at circumferentially predetermined pitches. Thus, when plating is not performed, the plating liquid is passed through the through holes 224, and is discharged to the exterior through the second plating liquid discharge ports 59, thereby controlling the liquid level of the plating liquid. During plating, the through holes 224 serve as an orifice for restricting the amount of the plating liquid flowing therethrough.

[0051] As shown in FIG. 5, the first plating liquid discharge ports 57 are connected to the reservoir 226 through the plating liquid discharge pipe 60a, and a flow controller 61a is provided in the plating liquid discharge pipe 60a. The second plating liquid discharge ports 59

and the third plating liquid discharge ports 120 join with each other within the plating container 50, and the joined passage is then connected directly to the reservoir 226 through the plating liquid discharge pipe 60b.

[0052] The reservoir 226 is constructed so that the plating liquid from all the other plating units flows into the reservoir 226. The plating liquid which has flowed into the reservoir 226 is introduced by a pump 228 into the plating liquid regulating tank 40 (see FIG. 3). This plating liquid regulating tank 40 is provided with a temperature controller 230, and a plating liquid analyzing unit 232 for sampling the plating liquid and analyzing the sample solution. When a single pump 234 is operated, the plating liquid is supplied from the plating liquid regulating tank 40 through the filter 236 to the plating liquid supply nozzles 53 in each of the plating units. A control valve 56 is provided in the plating liquid supply pipe 55 extending from the plating liquid regulating tank 40 to each of the plating units. This control valve 56 serves to make the pressure on the secondary side constant, and, even when one plating unit is stopped, the control valve 56 can make the supply pressure of the plating liquid in the other plating units constant.

[0053] Thus, a plating liquid prepared in a plating liquid regulating tank 40 in a single plating process system is fed to a plurality of plating units through a single pump 234. The plating liquid preparation tank 40 having a large capacity is used in the plating process system to prepare a plating liquid. With this arrangement, the plating liquid is fed to each of the plating units while controlling the flow rate in each of the plating units through control valves 56, and a variation of the plating liquid in quality can be suppressed.

[0054] As shown in FIG. 4 a vertical stream regulating ring 62 and a horizontal stream regulating ring 63 are disposed within the plating chamber 49 at a position near the internal circumference of the plating chamber 49, and the central portion of the liquid surface is pushed up by an upward stream out of two divided upward and downward streams of the plating liquid 45 within the plating chamber 49, whereby the downward flow is smoothened and the distribution of the current density is further uniformized. The horizontal stream regulating ring 63 has a peripheral portion which is fixed to the plating container 50, and the vertical stream regulating ring 62 is connected to the horizontal stream regulating ring 63.

[0055] On the other hand, the head 47 comprises a housing 70 which is a rotatable and cylindrical receptacle having a downwardly open end and has openings 96 on the circumferential wall, and vertically movable pressing rods 242 having, in its lower end, a pressing ring 240. As shown in FIGS. 8 and 9, an inwardly projecting ring-shaped substrate holding member 72 is provided at the lower end of the housing 70. A ring-shaped sealing member 244 is mounted on the substrate holding member 72. The ring-shaped sealing member 244 projects inward, and the front end of the top surface in

the ring-shaped sealing member 244 projects upward in an annular tapered form. Further, contacts 76 for a cathode electrode are disposed above the sealing member 244. Air vent holes 75, which extend outwardly in the horizontal direction and further extend outwardly in an upwardly inclined state, are provided in the substrate holding member 72 at circumferentially equal intervals.

[0056] With this arrangement, as shown in FIG. 6, the liquid level of the plating liquid is lowered, and as shown in FIGS. 8 and 9, the substrate W is held by a robot hand H or the like, and inserted into the housing 70 where the substrate W is placed on the upper surface of the sealing member 244 of the substrate holding member 72. Thereafter, the robot hand H is withdrawn from the housing 70, and the pressing ring 240 is then lowered to sandwich the peripheral portion of the substrate W between the sealing member 244 and the lower surface of the pressing ring 240, thereby holding the substrate W. In addition, upon holding of the substrate W, the lower surface of the substrate W is brought into pressure contact with the sealing member 244 to seal this contact portion positively. At the same time, current flows between the substrate W and the contacts 76 for a cathode electrode.

[0057] Returning to FIG. 4, the housing 70 is connected to an output shaft 248 of a motor 246, and rotated by energization of the motor 246. The pressing rods 242 are vertically provided at predetermined positions along the circumferential direction of a ring-shaped support frame 258 rotatably mounted through a bearing 256 on the lower end of a slider 254. The slider 254 is vertically movable by actuation of a cylinder 252, with a guide, fixed to a support 250 surrounding the motor 246. With this construction, the pressing rods 242 are vertically movable by the actuation of the cylinder 252, and, in addition, upon the holding of the substrate W, the pressing rods 242 are rotated integrally with the housing 70.

[0058] The support 250 is mounted on a slide base 262 which is engaged with a ball screw 261 and vertically movable by the ball screw 261 rotated by energization of the motor 260. The support 250 is surrounded by an upper housing 264, and is vertically movable together with the upper housing 264 by energization of the motor 260. Further, a lower housing 266 for surrounding the housing 70 during plating is mounted on the upper surface of the plating container 50.

[0059] With this construction, as shown in FIG. 7, maintenance can be performed in such a state that the support 250 and the upper housing 264 are raised. A crystal of the plating liquid is likely to deposit on the inner circumferential surface of the weir member 58. However, the support 250 and the upper housing 264 are raised, a large amount of the plating liquid is flowed and overflows the weir member 58, and hence the crystal of the plating liquid is prevented from being deposited on the inner circumferential surface of the weir member 58. A cover 50b for preventing the splash of the plating liquid is integrally provided in the plating container 50 to cover

a portion above the plating liquid which overflows during plating process. By coating an ultra-water-repellent material such as HIREC (manufactured by NTT Advance Technology) on the lower surface of the cover 50b for preventing the splash of the plating liquid, the crystal of the plating liquid can be prevented from being deposited on the lower surface of the cover 50b.

[0060] Substrate centering mechanisms 270 located above the substrate holding member 72 of the housing 70 for performing centering of the substrate W, are provided at four places along the circumferential direction in this embodiment (see FIG. 13).

[0061] FIG. 11 shows the substrate centering mechanism 270 in detail. The substrate centering mechanism 270 comprises a gate-like bracket 272 fixed to the housing 70, and a positioning block 274 disposed within the bracket 272. This positioning block 274 is swingably mounted through a support shaft 276 horizontally fixed to the bracket 272 at its upper part. Further, a compression coil spring 278 is interposed between the housing 70 and the positioning block 274. Thus, the positioning block 274 is urged by the compression coil spring 278 so that the positioning block 274 rotates about the support shaft 276 and the lower portion of the positioning block 274 projects inwardly. The upper surface 274a of the positioning block 274 serves as a stopper, and is brought into contact with the lower surface 272a of the bracket 272 to restrict the movement of the positioning block 274. Further, the positioning block 274 has a tapered inner surface 274b which is widened outward in the upward direction.

[0062] With this construction, a substrate is held by the hand H of a transfer robot or the like, is carried into the housing 70, and is placed on the substrate holding member 72 (see FIG. 8). In this case, when the center of the substrate deviates from the center of the substrate holding member 72, the positioning block 274 is rotated outwardly against the urging force of the compression coil spring 278 and, upon the release of holding of the substrate from the hand of the transfer robot or the like, the positioning block 274 is returned to the original position by the urging force of the compression coil spring 278. Thus, the centering of the substrate can be carried out.

[0063] FIG. 12 shows a feeding contact (a probe) 77 for feeding power to a cathode electrode plate 208 of a contact 76 for a cathode electrode. This feeding contact 77 is composed of a plunger and is surrounded by a cylindrical protective member 280 extending to the cathode electrode plate 208, whereby the feeding contact 77 is protected against the plating liquid.

[0064] In this case, when plating process is carried out, an annular substrate-contacting portion 360 (see FIG. 16) projecting from the inner circumferential surface of the sealing member 244, is pressed against the surface, to be plated, of the substrate. The inner side of the substrate-contacting portion 360 is filled with the plating liquid. Therefore, the plating liquid remains on



the substrate-contacting portion or its vicinity. This plating liquid, upon drying, becomes a source for particles. For this reason, in this embodiment, a plating liquid removing mechanism 300 is provided for removing the plating liquid remaining on the substrate-contacting portion or its vicinity of the sealing member 244.

[0065] FIGS. 13 through 15 show the plating liquid removing mechanism 300. The plating liquid removing mechanism 300 includes a nozzle head 302 in the shape of an arc with a central angle of e.g. about  $100^\circ$  extending along the substrate-contacting portion 360 at the inner circumferential edge of the sealing member 244. In the inside of the nozzle head 302, a plating liquid passage 302a and a cleaning liquid passage 302b are formed substantially in parallel, extending in the long direction of the nozzle head 302. At each end of the nozzle head 302, there are provided one bottom-opened suction nozzles 302c that communicates with the plating liquid passage 302a, and two bottom-opened cleaning liquid injection nozzles 302d that communicate with the cleaning liquid passage 302b. The cleaning liquid injection nozzles 302d are disposed on both sides of the plating liquid suction nozzles 302c at each end of the nozzle head 302.

[0066] The nozzle head 302 is connected, through a block 306, to the lower end of a nozzle support 304 that extends horizontally and turns halfway down to the vertical direction and extends downwardly. In the inside of the nozzle support 304, there are formed a plating liquid passage 304a and a cleaning liquid passage 304b, which respectively communicate with the plating liquid passage 302a and the cleaning liquid passage 302b. The plating liquid passage 304a is connected, via a flexible tube 312a, to a vacuum source 310; and the cleaning liquid passage 304b is connected, via a flexible tube 312b, to a cleaning liquid supply source 313.

[0067] The nozzle support 304 is connected to a horizontal slider 316 that moves horizontally by the actuation of a cylinder 314 for horizontal movement. The cylinder 314 for horizontal movement is connected, through a hooked bracket 322, to a vertical slider 320 that moves vertically by the actuation of a cylinder 318 for vertical movement. The cylinder 318 for vertical movement is mounted on the above described support 250. Therefore, the nozzle head 302 is horizontally and vertically movable.

[0068] FIG. 16 is an enlarged view of the main portion of the sealing member 244. A substrate-contacting portion 360, which is in the shape of a spire in cross section and is projecting upwardly, is formed at the inner circumferential upper edge of the sealing member 244. The outline of the substrate-contacting portion 360 is defined by: a top flat surface 362 which is positioned slightly outward from a plane extending upwardly from the inner circumferential end surface of the sealing member 244 and extends horizontally; a reverse tapered surface 364 which makes an acute angle  $\theta_1$  with a horizontal plane and extends inwardly from the top flat surface 362; and

a tapered surface 366 which makes an acute angle  $\theta_2$  with a horizontal plane and extends outwardly from the top flat surface 362. Thus, the substrate-contacting portion 360 is in the shape of an acute-angle triangle in cross section, with the top being flattened. The angle  $\theta_1$  between the reverse tapered surface 364 and the horizontal plane is designed to be larger than the angle  $\theta_2$  between the tapered surface 366 and the horizontal plane ( $\theta_1 > \theta_2$ ).

[0069] Due to the specific configuration, the substrate-contacting portion 360 of the sealing member 244 possesses an enhanced rigidity. Further, the provision of the reverse tapered surface 364 on the inner plating liquid-contacting side can keep the plating liquid on the inner reverse tapered surface 364, after the plating treatment, not allowing the plating liquid to flow to the outer side. Thus, as shown in FIG. 16B, when the plating is performed while contacting the substrate W with the substrate-contacting portion 360 and pressing the substrate W by applying a sufficient load F to fully seal the outer peripheral edge of the substrate W, the plating liquid P stays between the substrate W and the reverse tapered surface 364. After the substrate W is taken off, the plating liquid P is stemmed by the top flat surface 362 and prevented from flowing down to the outer electrical contact side.

[0070] In the case of a conventional sealing member commonly used, as shown in FIG. 17, it has a substrate-contacting portion (sealing portion) 384 which is in the shape of an obtuse-angle triangle, in cross section, with the two tapered surfaces 380 and 382 making an obtuse angle with each other. The substrate is sealed at the pointed top of the substrate-contacting portion 384. When plating is performed while contacting the substrate W with the substrate-contacting portion 384 and pressing the substrate W by applying a sufficient load F to fully seal the outer peripheral edge of the substrate W, as shown in FIG. 17B, the top of the substrate-contacting portion 384 is forced to hang down beneath the substrate W due to the load F, and the plating liquid P stays between the substrate W and the thus hung portion of the sealing member. When the substrate W is taken off and the substrate-contacting portion 384, due to its elasticity, is restored to the original state, the plating P flows down to the outer electrical contact side, as shown in FIG. 17A.

[0071] The plating liquid, which has flown down to the outer electrical contact side, is hard to remove by suction and becomes the source of generating particles. Moreover, the plating liquid corrodes the electrical contacts and, in addition, forms a local electric cell between the electrical contacts and the substrate-contacting portion whereby the appearance of the substrate is deteriorated. According to this embodiment of the present invention, the plating liquid is prevented from flowing to the outer electrical contact side, and therefore, the above drawbacks can be avoided.

[0072] Further, according to this embodiment, the

sealing member 244 is made of a high-tearing strength silicone rubber that has a higher water-repellency than a fluorine rubber and an ethylene/propylene rubber, and has a sufficiently high tensile strength. The use of such a highly water-repellent sealing member 244, which is to be contacted with the substrate, can reduce the amount of the plating liquid that remains on the surface thereof.

[0073] Specifically, conventional sealing members are generally made of a fluorine rubber or an ethylene/propylene rubber. FIG. 18 shows comparative data regarding the change of contact angle ( $\theta$ ) between a sealing member made of a fluorine rubber and a sealing member made of a silicone rubber having a higher water-repellency, in which the contact angle data for the respective members after 762.65-hour dipping in a plating liquid is shown together with the data for the undipped members. As shown in FIG. 18, in the case of the sealing member made of fluorine rubber, the contact angle decreases from  $80^\circ$  (undipped member) to  $76^\circ$  (dipped member), indicating the deterioration of the water-repellency. In contrast, there is seen no substantial change in contact angle (from  $91^\circ$  to  $92^\circ$ ) for the sealing member made of silicone rubber, thus indicating no deterioration of the water-repellency.

[0074] Ordinary silicone rubbers have a tensile strength of about 8 MPa (80 kgf/cm<sup>2</sup>), which is half the tensile strength of fluorine rubbers, i.e. about 16 MPa (160 kgf/cm<sup>2</sup>). In the case of a high tearing-strength silicone rubber, on the other hand, it has an enhanced tensile strength of about 10-12 MPa (100-120 kgf/cm<sup>2</sup>). A sealing member made of this particular silicone rubber thus does not suffer from the shortage of strength.

[0075] The operation of the plating unit 22 will now be described.

[0076] First, in transferring the substrate to the plating unit 22, the attracting hand of the second transfer device 24 shown in FIG. 2, and the substrate W attracted and held with its front surface downward by the attracting hand are inserted into the housing 70 through the opening 96, and the attracting hand is then moved downward. Thereafter, the vacuum attraction is released to place the substrate W on the substrate holding member 72. The attracting hand is then moved upward and withdrawn from the housing 70. Thereafter, the pressing ring 240 is lowered down to the peripheral edge of the substrate W so as to hold the substrate W between the substrate holding member 72 and the lower surface of the pressing ring 240.

[0077] The plating liquid 45 is then spurted from the plating liquid supply nozzles 53 while, at the same time, the housing 70 and the substrate W held by it are allowed to rotate at a middle speed (100-250 min<sup>-1</sup>, e.g. 150 min<sup>-1</sup>). When the plating chamber is charged with a predetermined amount of the plating liquid 45, and further after an elapse of several seconds, the rotational speed of the housing 70 is decreased to a slow rotation (10-225 min<sup>-1</sup>, e.g. 100 min<sup>-1</sup>). Then, electroplating is

carried out by flowing a plating current between the anode 48 and the surface, to be plated, of the substrate as a cathode.

[0078] After the feed of the plating current, as shown in FIG. 10D, the amount of supply of the plating liquid is decreased so that the liquid is allowed to flow out only through the through holes 224 for liquid level control positioned above the plating liquid supply nozzles 53, thereby exposing the housing 70, together with the substrate held by it, above the surface of the plating liquid. The housing 70 and the substrate W, positioned above the liquid surface, are allowed to rotate at a high speed (e.g. 500-1000 min<sup>-1</sup>) to dewater the plating liquid by the action of centrifugal force. After the completion of dewatering, the rotation of the housing 70 is stopped so that the housing 70 stops at a predetermined position.

[0079] After the housing 70 comes to a complete stop, the pressing ring 240 is moved upward. Thereafter, the attracting hand of the second transfer device 24 is inserted, with its attracting face downward, into the housing 70 through the opening 96 and is then lowered to a position at which the attracting hand can attract the substrate. After attracting the substrate by vacuum attraction, the attracting hand is moved upward to the position of the opening 96 of the housing 70, and is withdrawn, together with the substrate held by the hand, through the opening 96.

[0080] According to the plating unit 22, the head 47 can be designed to be compact and structurally simple. Further, the plating can be performed when the surface of the plating liquid in the plating process container 46 lies at the plating level, and the dewatering and the transfer of the substrate can be conducted when the surface of the plating liquid lies at the substrate transferring level. Moreover, the black film formed on the surface of the anode 48 can be prevented from being dried and oxidized.

[0081] When the above-described plating treatment is repeatedly performed, the amount of the plating liquid remaining on the substrate-contacting portion 360 or its vicinity of the sealing member 244 gradually increases though the sealing member 244 is used made of a high-tearing strength silicone having a high water-repellency and the plating liquid remaining to the substrate-contacting portion 360 or its vicinity of the sealing member 244 is dewatered by centrifugal force by rotating the substrate at a high speed. Accordingly, for every several times (for example five times) of plating treatments, or at any time according to need, suction-removing of the plating liquid remaining on the substrate-contacting portion 360 or its vicinity of the sealing member 244 is conducted by using the plating liquid removing mechanism 300. The suction-removing treatment may of course be conducted for every plating treatment.

[0082] Specifically, the dewatering (spin-drying) of the plating liquid is carried out by rotating the housing 70 at a high speed (500-1000 min<sup>-1</sup>) while the substrate is held by the substrate holding member 72, thereby de-

watering the superfluous plating liquid on the substrate and the plating liquid staying on the substrate-contacting portion 360 or its vicinity of the sealing member 244. After the dewatering is completed and the substrate is taken out of the housing 70, the cylinder 314 for horizontal movement is actuated to move the nozzle head 302 toward the housing 70 and introduce it into the housing 70 through the opening 96 of the housing 70. Thereafter, the cylinder 318 for vertical movement is actuated to lower so that the nozzle head 302 approaches and faces the substrate-contacting portion 360 of the sealing member 244.

[0083] In this state, while rotating the housing 70 slowly in both directions (1-10 min<sup>-1</sup>), sucking of the plating liquid by the actuation of the vacuum source 310 is conducted and, at the same time, a jet of a cleaning liquid such as pure water is ejected from the cleaning liquid injection nozzles 302d toward the substrate-contacting portion 360 or its vicinity of the sealing member 244, thereby cleaning the substrate-contacting portion 360 or its vicinity of the sealing member 244. Thus, the plating liquid remaining on the substrate-contacting portion 360 or its vicinity of the sealing member 244 is sucked, together with the cleaning liquid used for the cleaning of the sealing member 244, by the plating liquid suction nozzles 302c. This can prevent the plating liquid from remaining in the inside of the plating liquid suction nozzles 302c and clogging the nozzles when the plating liquid is dried.

[0084] The above suction-removing treatment effects removal of the plating liquid remaining on half of the entire substrate-contacting portion 360 or its vicinity of the sealing member 244. After the completion of the treatment, the nozzle head 302 is withdrawn from the housing 70 in the opposite manner to the above, and the housing 70 is rotated horizontally by 180°. Thereafter, the nozzle head 302 is inserted into the housing 70 through an opening 96 facing the substrate contacting portion 360 or its vicinity of the sealing member 244 in the same manner as described above. The same suction-removing treatment is then carried out to effect removal of the plating liquid remaining on the other half of the entire substrate-contacting portion 360 or its vicinity of the sealing member 244.

[0085] The above plating liquid-removing treatment can suck and remove the plating liquid remaining on the substrate-contacting portion 360 or its vicinity of the sealing member 244 efficiently in a short time, thus preventing an unremoved plating liquid becoming the source of particle generation. Further, clogging of the plating liquid suction nozzles 302c caused by the residue of the sucked plating liquid can be prevented.

[0086] It is also possible to easily remove the plating liquid remaining on the substrate-contacting portion 360 or its vicinity of the sealing member 244 merely by the sucking treatment using the plating liquid suction nozzles 302c, without employing the cleaning treatment us-

ing the cleaning liquid injection nozzles 302d, when the treatment is conducted at short intervals, such as the case where the treatment is conducted for every plating treatment.

[0087] As described hereinabove, according to the present invention, the plating liquid remaining on the substrate-contacting portion or its vicinity at the inner circumferential edge of the substrate holding member can be fully sucked and removed, forcibly. This can avoid the problem of particle generation which would be caused by an unremoved plating liquid when it is dried. Further, the plating apparatus of the present invention, which allows the substrate holding member to rotate, ensures a good embedding of the plated film in forming copper interconnects e.g. by the damascene method and performs an improved plating, and in addition, can easily and promptly remove the plating liquid remaining on the substrate-contacting portion or its vicinity of the substrate holding member. The plating apparatus eliminates the need to rotate the plating liquid-removing means, thus enabling a simplified apparatus structure that requires a smaller space for installation.

[0088] Although certain preferred embodiments of the present invention have been shown and described in detail, it should be understood that various changes and modifications may be made therein without departing from the scope of the appended claims.

## Claims

### 1. A plating apparatus, comprising:

a head having a rotatable housing provided with a substrate holding member for holding a substrate;  
a plating process container, disposed below said head, for holding a plating liquid therein; and  
a plating liquid removing mechanism for removing a plating liquid remaining on a substrate-contacting portion or its vicinity at an inner circumferential edge of said substrate holding member.

2. The plating apparatus according to claim 1, wherein said plating liquid removing mechanism has a plating liquid suction nozzle which can move close to said substrate-contacting portion at the inner circumferential edge of said substrate holding member and sucks the plating liquid remaining on said substrate-contacting portion or its vicinity.

3. The plating apparatus according to claim 2, wherein said plating liquid removing mechanism also has a cleaning liquid injection nozzle which can move close to said substrate-contacting portion at the inner circumferential edge of said substrate holding

member and ejects a cleaning liquid toward said substrate-contacting portion or its vicinity.

4. A plating apparatus, comprising:

a head having a rotatable housing provided with a substrate holding member for holding a substrate; and  
a plating process container, disposed below said head, for holding a plating liquid therein;

wherein said substrate holding member is provided with a sealing member for sealing an outer peripheral edge of the substrate, said sealing member being made of a highly water-repellent material.

5. A plating apparatus, comprising:

a head having a rotatable housing provided with a substrate holding member for holding a substrate;  
a plating process container, disposed below said head, for holding a plating liquid therein; and  
a plating liquid removing mechanism for removing a plating liquid remaining on a substrate-contacting portion or its vicinity at an inner circumferential edge of said substrate holding member;

wherein said substrate holding member is provided with a sealing member for sealing an outer peripheral edge of the substrate, said sealing member being made of a highly water-repellent material.

6. The plating apparatus according to claim 5, wherein said plating liquid removing mechanism has a plating liquid suction nozzle which can move close to said substrate-contacting portion at the inner circumferential edge of said substrate holding member and sucks the plating liquid remaining on said substrate-contacting portion or its vicinity.

7. The plating apparatus according to claim 6, wherein said plating liquid removing mechanism also has a cleaning liquid injection nozzle which can move close to said substrate-contacting portion at the inner circumferential edge of said substrate holding member and ejects a cleaning liquid toward said substrate-contacting portion or its vicinity.

8. A plating apparatus, comprising:

a head having a rotatable housing provided with a substrate holding member for holding a substrate; and  
a plating process container, disposed below said head, for holding a plating liquid therein;

wherein said substrate holding member is provided with a sealing member for sealing an outer peripheral edge of the substrate, said sealing member having a substrate-contacting portion which is in a shape of a spire, in cross section, with a flat top surface.

9. A plating apparatus, comprising:

a head having a rotatable housing provided with a substrate holding member for holding a substrate;  
a plating process container, disposed below said head, for holding a plating liquid therein; and  
a plating liquid removing mechanism for removing a plating liquid remaining on a substrate-contacting portion or its vicinity at an inner circumferential edge of said substrate holding member;

wherein said substrate holding member is provided with a sealing member for sealing an outer peripheral edge of the substrate, said sealing member having a substrate-contacting portion which is in a shape of a spire, in cross section, with a flat top surface.

10. The plating apparatus according to claim 9, wherein said plating liquid removing mechanism has a plating liquid suction nozzle which can move close to said substrate-contacting portion at the inner circumferential edge of said substrate holding member and sucks the plating liquid remaining on said substrate-contacting portion or its vicinity.

11. The plating apparatus according to claim 10, wherein said plating liquid removing mechanism also has a cleaning liquid injection nozzle which can move close to said substrate-contacting portion at the inner circumferential edge of said substrate holding member and ejects a cleaning liquid toward said substrate-contacting portion or its vicinity.

12. A method for removing a plating liquid remaining on a substrate-contacting portion or its vicinity at an inner circumferential edge of a substrate holding member for holding a substrate, comprising:

rotating said substrate holding member to remove the plating liquid from said substrate holding member; and  
sucking the plating liquid remaining on said substrate-contacting portion or its vicinity of said substrate holding member, while said substrate holding member is rotated.

13. The method for removing a plating liquid remaining

on a substrate-contacting portion or its vicinity at an inner circumferential edge of a substrate holding member for holding a substrate according to claim 12, wherein said sucking the plating liquid is performed by a plating liquid suction nozzle which can move close to said substrate-contacting portion at the inner circumferential edge of said substrate holding member.

14. The method for removing a plating liquid remaining on a substrate-contacting portion or its vicinity at an inner circumferential edge of a substrate holding member for holding a substrate according to claim 13, further comprising a cleaning liquid injection nozzle which can move close to said substrate-contacting portion at the inner circumferential edge of said substrate holding member and ejects a cleaning liquid toward said substrate-contacting portion or its vicinity.

15. A plating method, comprising:

plating a substrate held by a substrate holding member of a rotatable housing;  
rotating said housing to remove a plating liquid remaining on the substrate and said substrate holding member;  
taking the substrate out of said housing; and  
sucking the plating liquid remaining on a substrate-contacting portion or its vicinity at the inner circumferential edge of the substrate holding member, while said substrate holding member is rotated.

16. The plating method according to claim 15, wherein said sucking the plating liquid is performed by a plating liquid suction nozzle which can move close to said substrate-contacting portion at the inner circumferential edge of said substrate holding member.

17. The plating method according to claim 16, further comprising a cleaning liquid injection nozzle which can move close to said substrate-contacting portion at the inner circumferential edge of said substrate holding member and ejects a cleaning liquid toward said substrate-contacting portion or its vicinity.

18. A plating apparatus comprising:

a head having a rotatable housing provided with a substrate holding member for holding a substrate;  
a plating process container, disposed below the head section, for holding a plating liquid therein; and  
a plating liquid removing mechanism for removing a plating liquid remaining on a substrate-

contacting portion or its vicinity at the inner circumferential edge of the substrate holding member;

wherein said plating liquid removing mechanism has a plating liquid sucking member which is allowed to be introduced into said housing through an opening of said opening and to move near to said substrate holding member, said plating liquid sucking member, when located so as to face said substrate holding member, sucks and removes the plating liquid remaining on said substrate-contacting portion or its vicinity at the inner circumferential edge of said substrate holding member, while said substrate holding member is rotated.

19. The plating apparatus according to claim 18, wherein said plating liquid removing mechanism has a plating liquid suction nozzle which can move close to said substrate-contacting portion at the inner circumferential edge of said substrate holding member and sucks the plating liquid remaining on said substrate-contacting portion or its vicinity.

20. The plating apparatus according to claim 19, wherein said plating liquid removing mechanism also has a cleaning liquid injection nozzle which can move close to said substrate-contacting portion at the inner circumferential edge of said substrate holding member and ejects a cleaning liquid toward said substrate-contacting portion or its vicinity.

21. A plating method, comprising:

plating a substrate held by a substrate holding member of a rotatable housing;  
rotating said housing to remove a plating liquid remaining on the substrate and said substrate holding member;  
taking the substrate out of said housing through an opening of said opening;  
causing a plating liquid-sucking member of a plating liquid removing mechanism to face said substrate holding member by introducing said plating liquid removing mechanism into said housing through said opening; and  
removing the plating liquid remaining on said substrate-contacting portion or its vicinity at an inner circumferential edge of a substrate holding member in such a state that said plating liquid-sucking member faces closely said substrate holding member, while said substrate holding member is rotated.

22. The plating method according to claim 21, wherein said plating liquid removing mechanism has a plating liquid suction nozzle which can move close to said substrate-contacting portion at the inner cir-

cumferential edge of said substrate holding member and sucks the plating liquid remaining on said substrate-contacting portion or its vicinity.

23. The plating method according to claim 22, wherein  
said plating liquid removing mechanism also has a  
cleaning liquid injection nozzle which can move  
close to said substrate-contacting portion at the in-  
ner circumferential edge of said substrate holding  
member and ejects a cleaning liquid toward said  
substrate-contacting portion or its vicinity.

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FIG. 1A

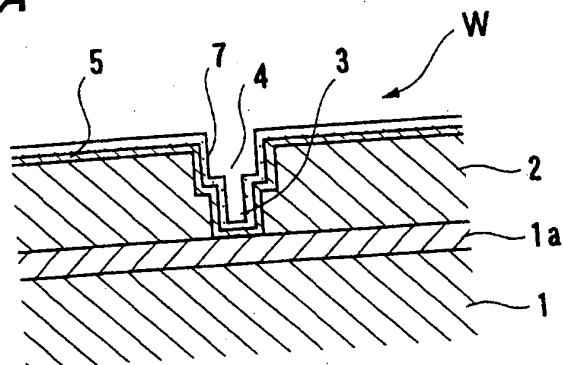


FIG. 1B

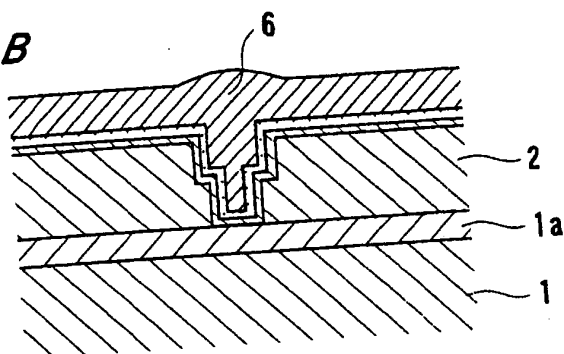


FIG. 1C

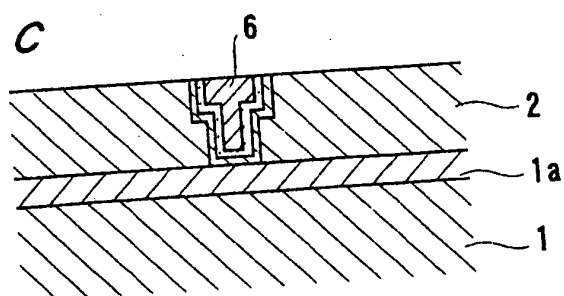


FIG. 2

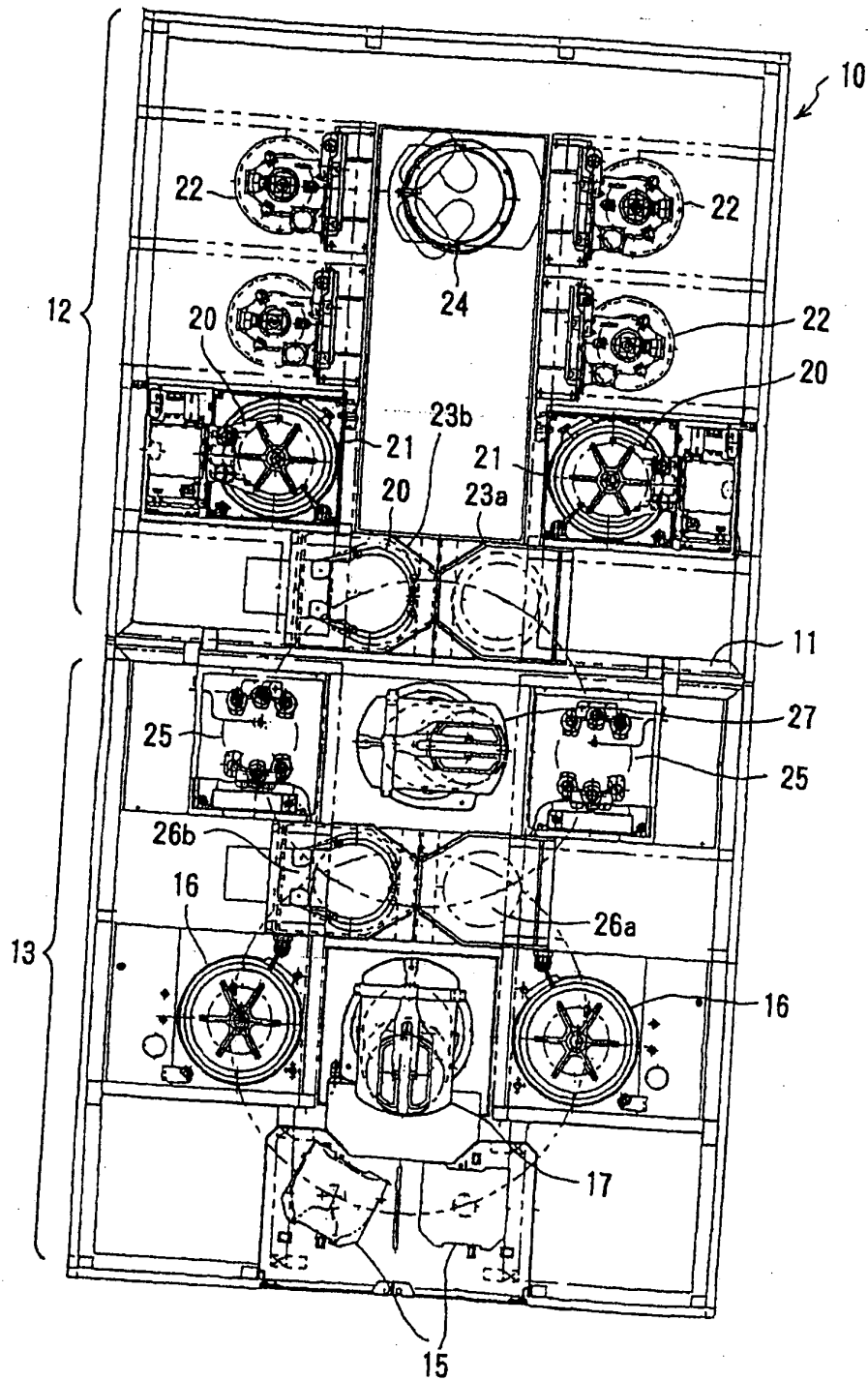




FIG. 3

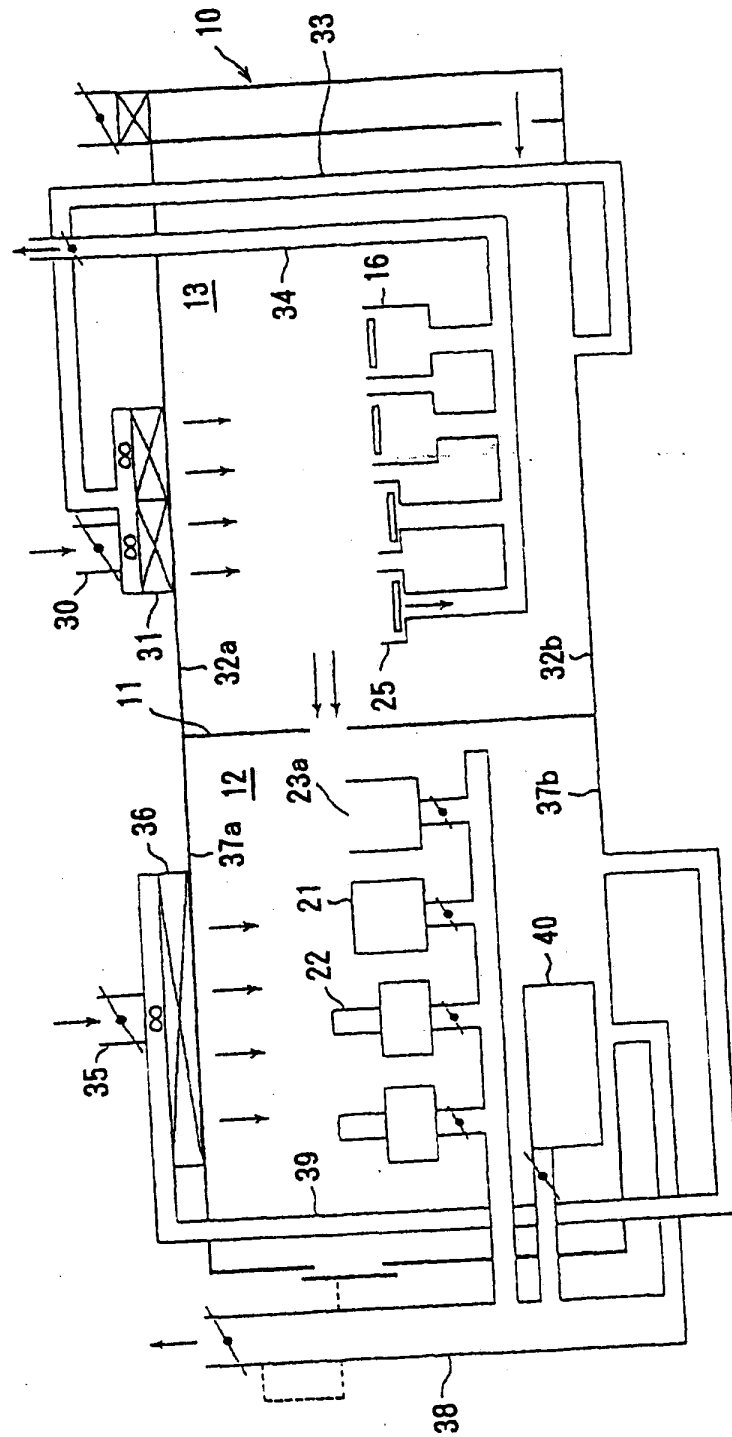


FIG. 4

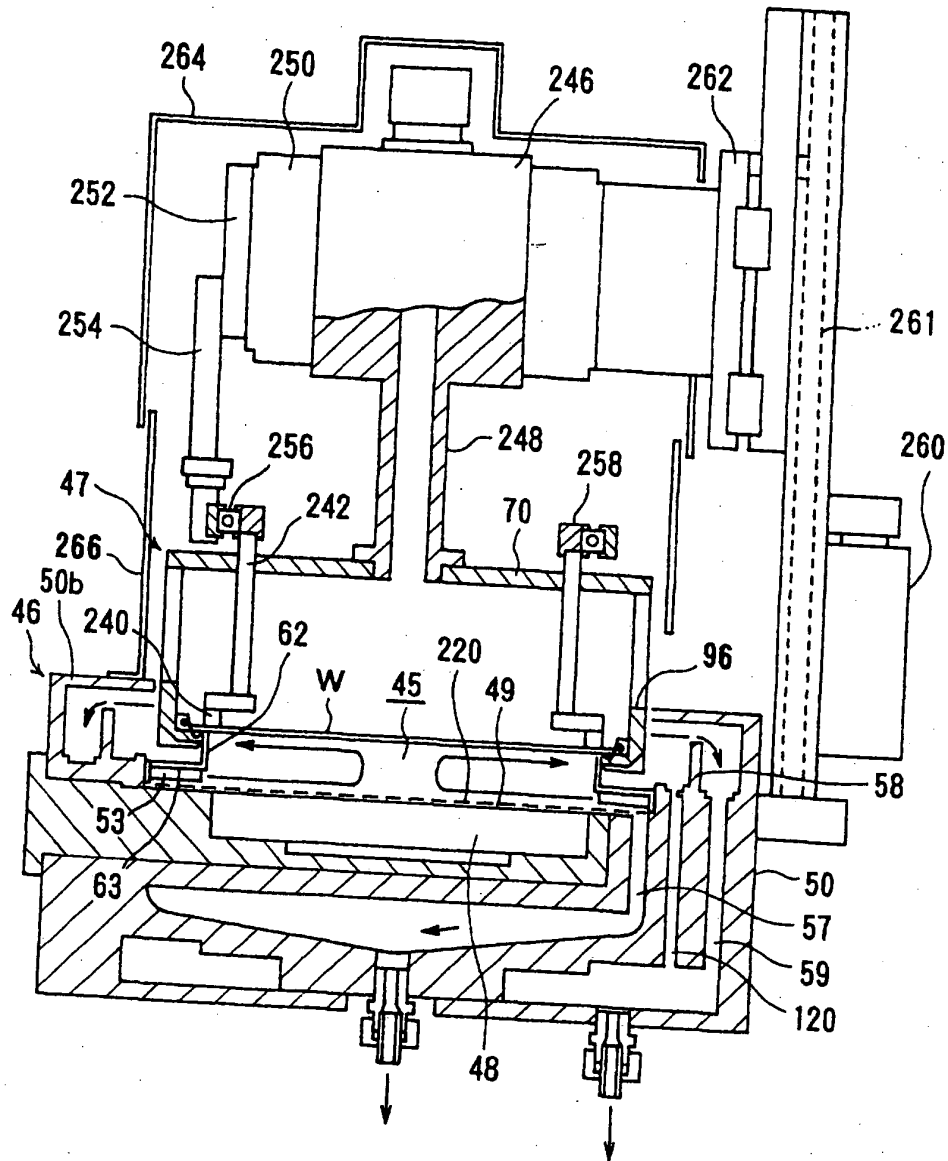
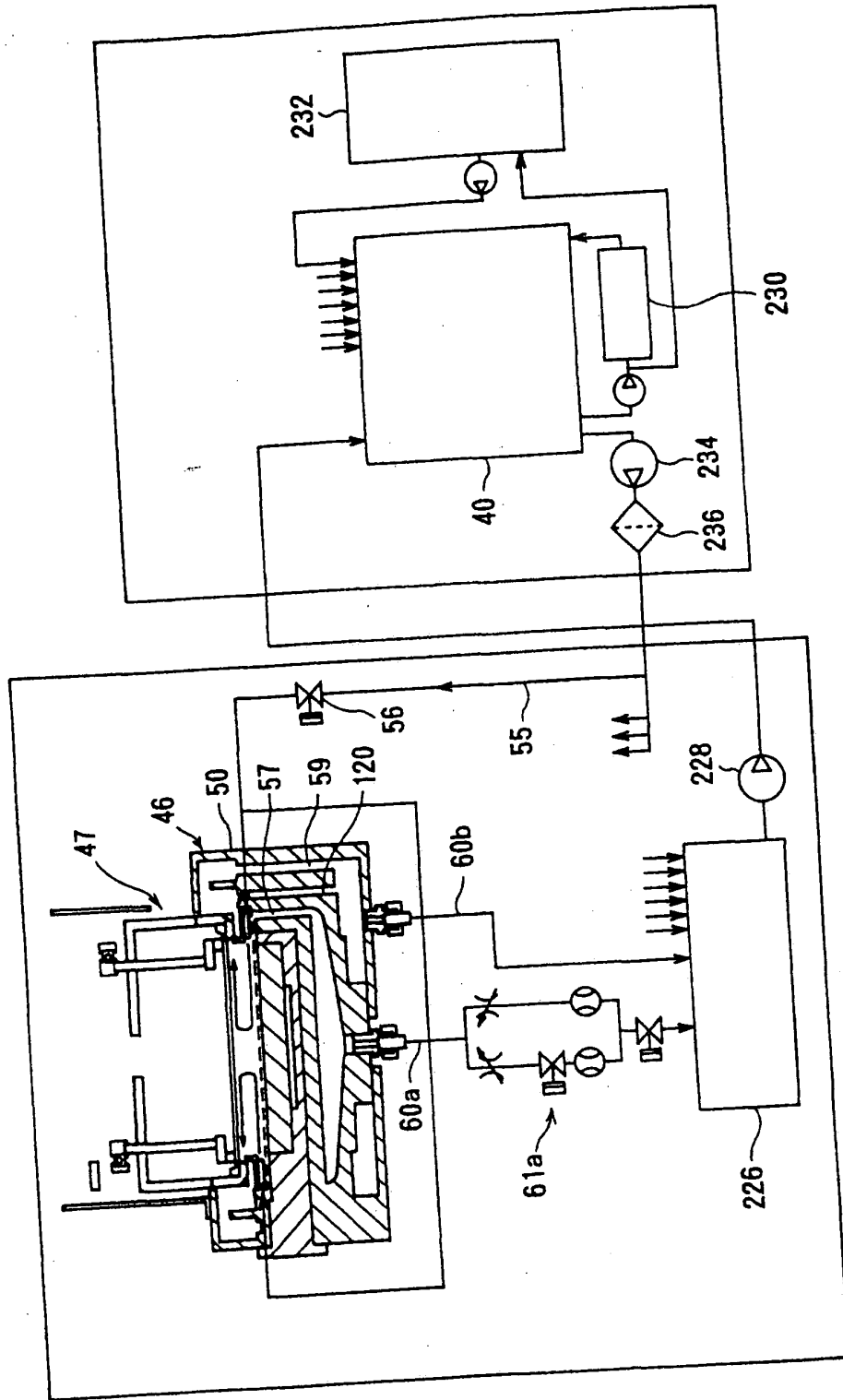
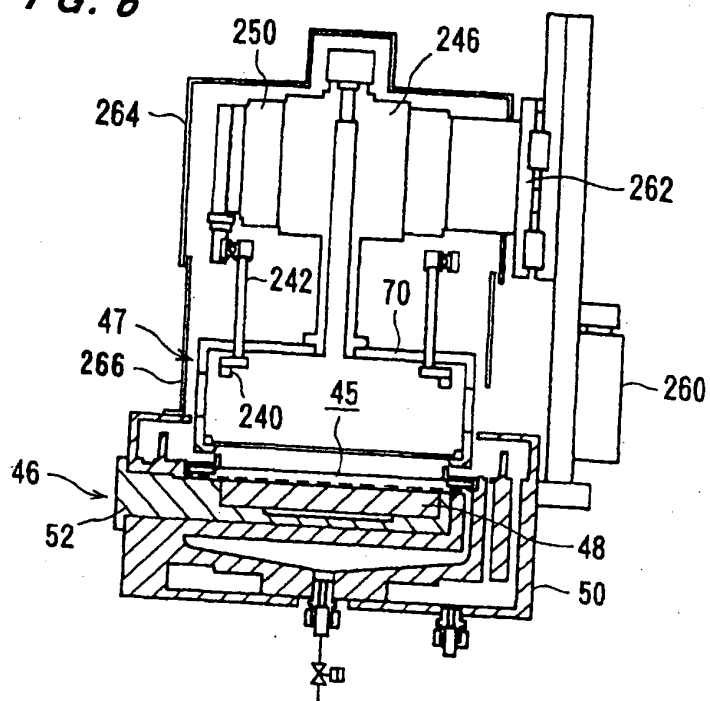


FIG. 5



**FIG. 6**



**FIG. 7**

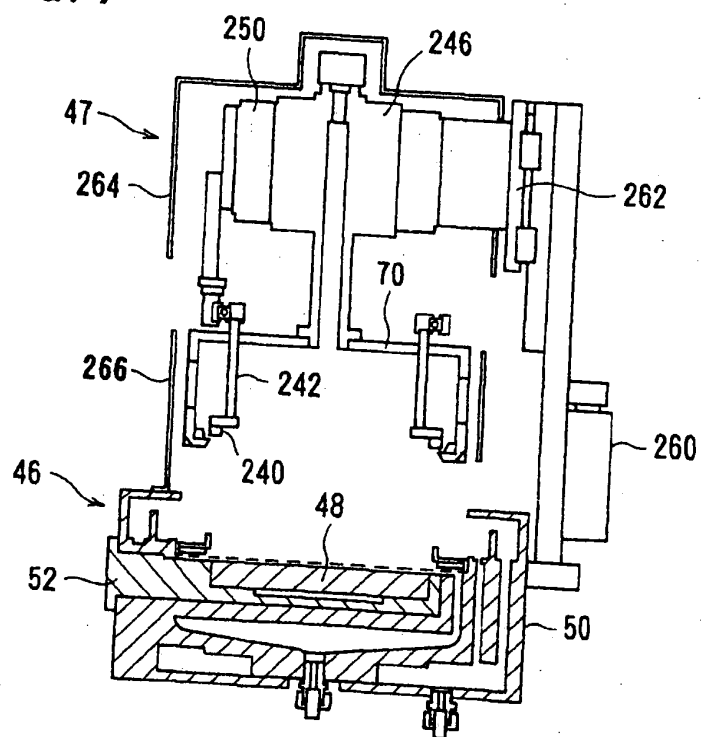


FIG. 8

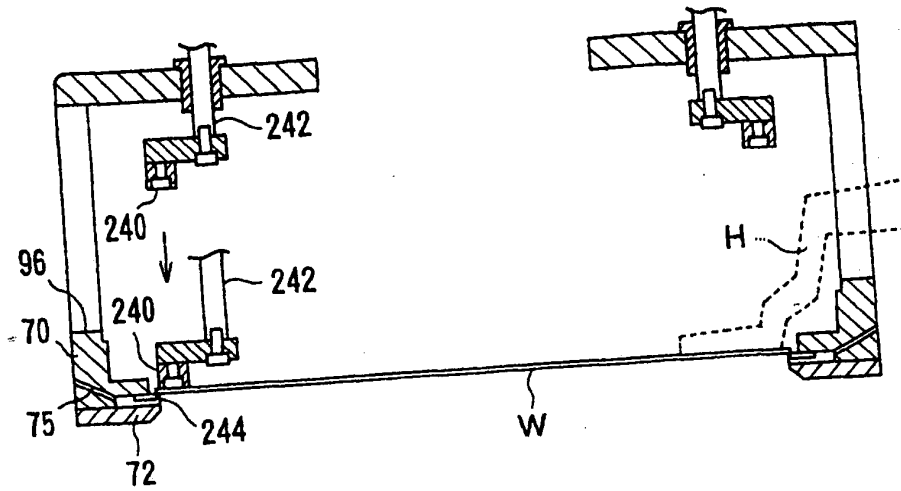


FIG. 9

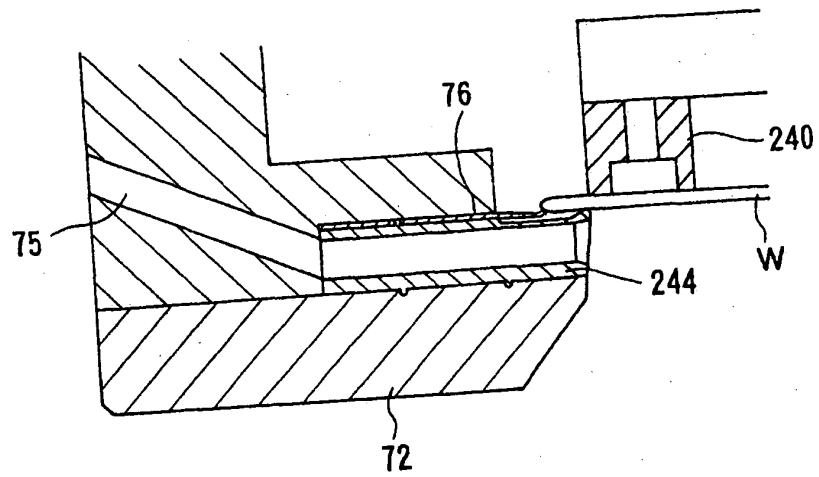


FIG. 10A

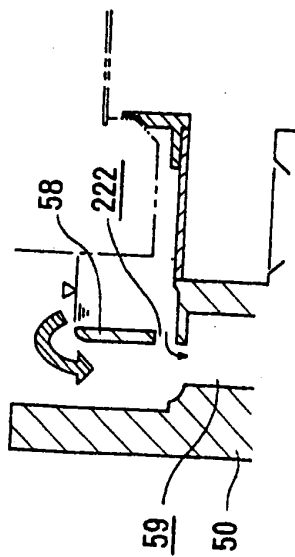


FIG. 10B

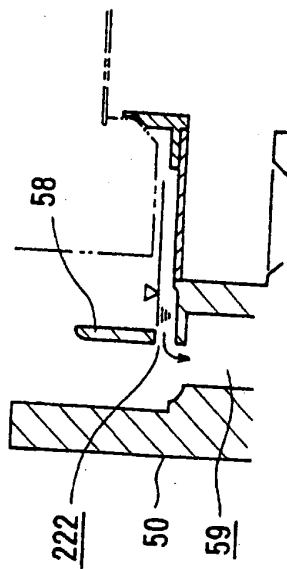


FIG. 10C

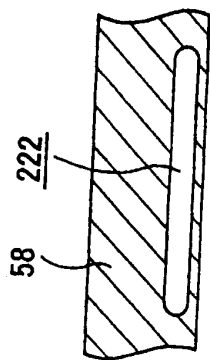
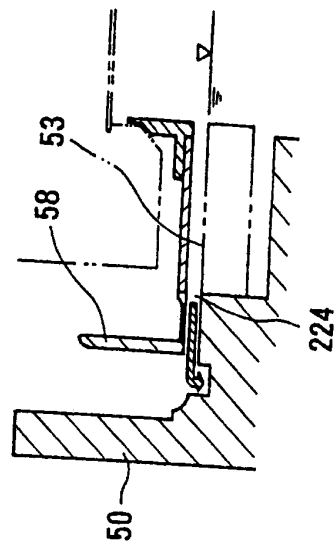
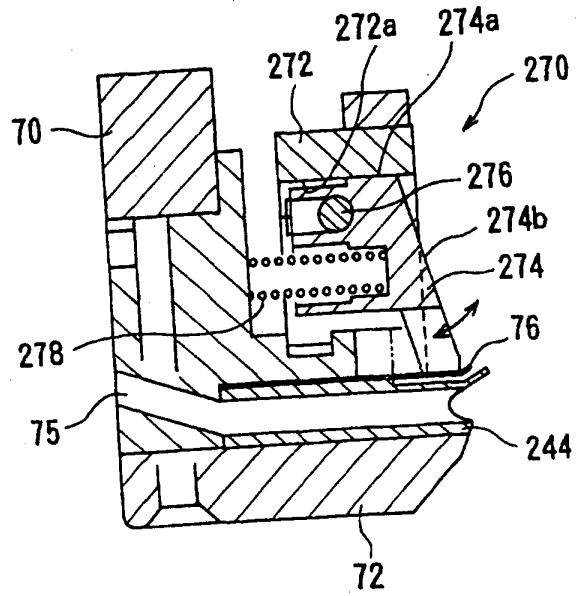


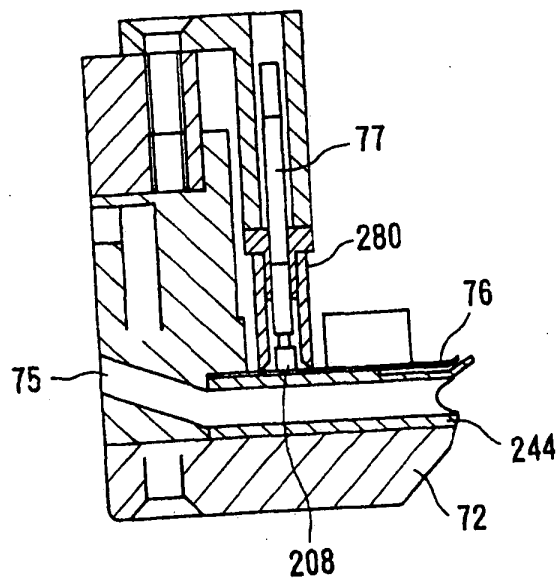
FIG. 10D



**FIG. 11**



**FIG. 12**



*FIG. 13*

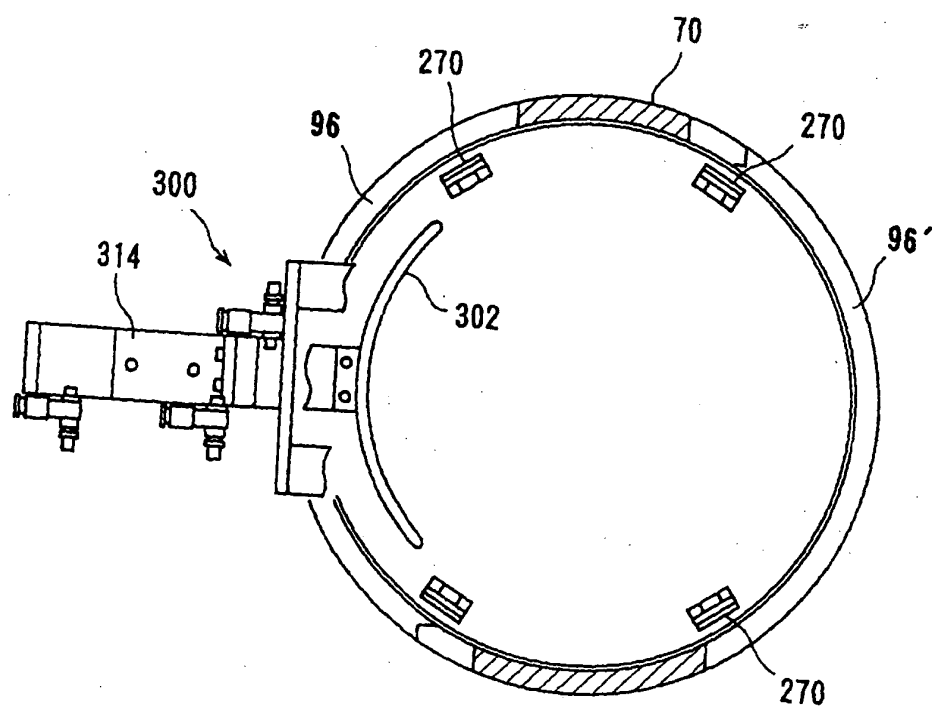




FIG. 14

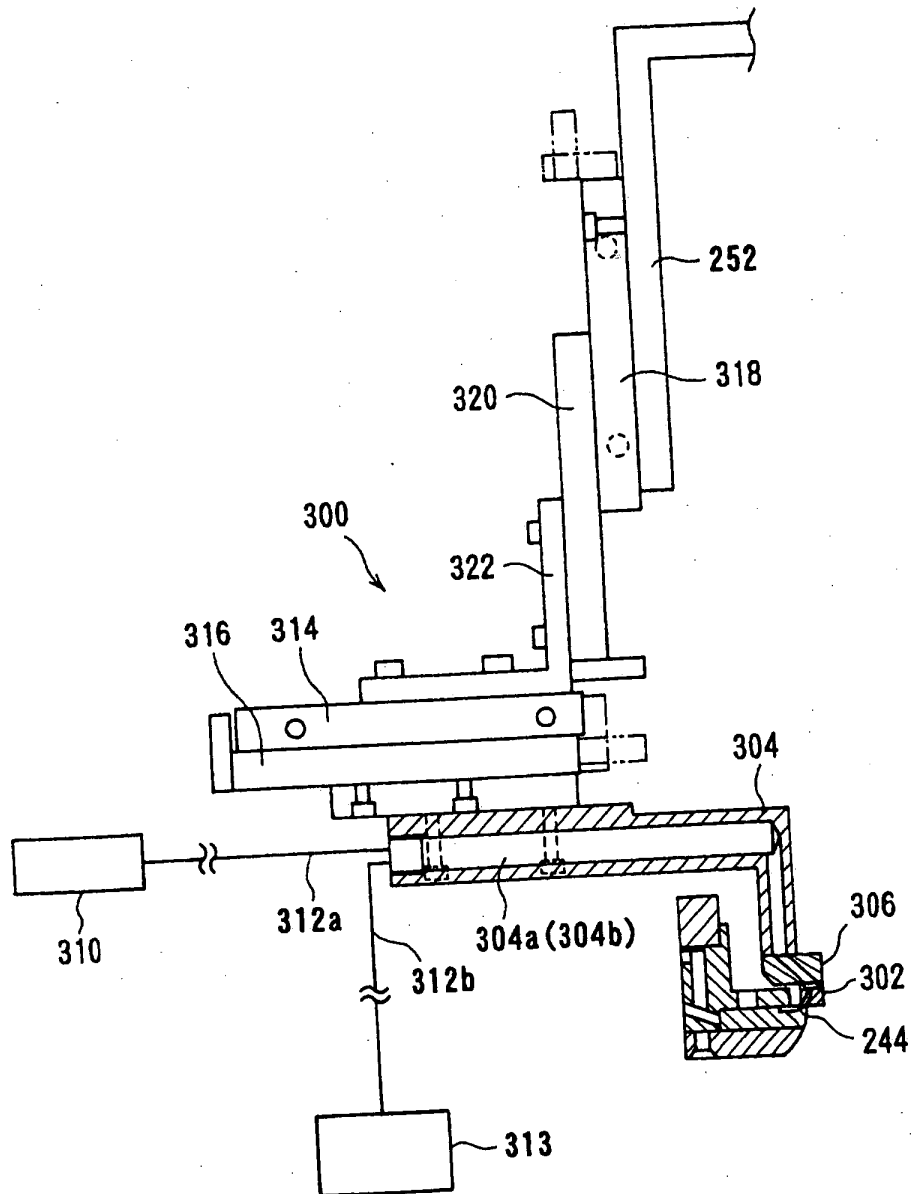
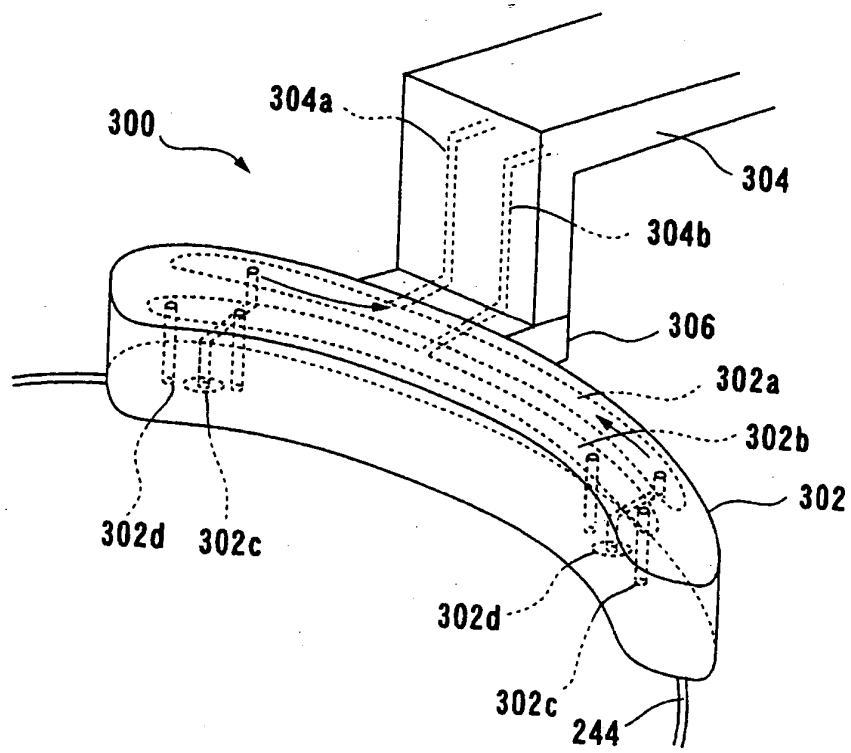
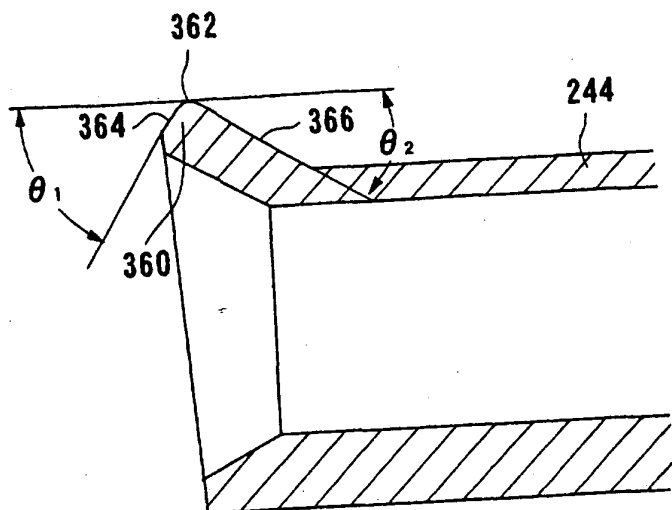


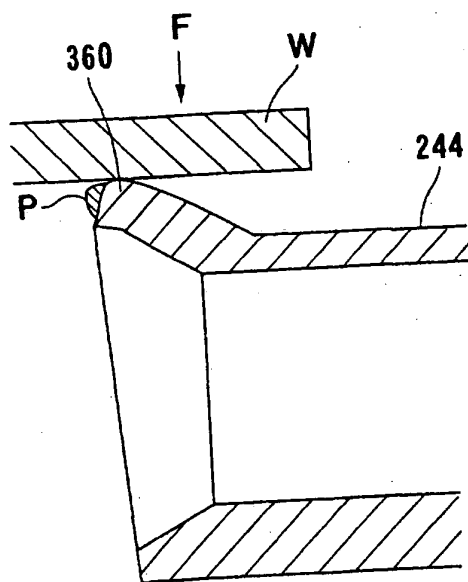
FIG. 15



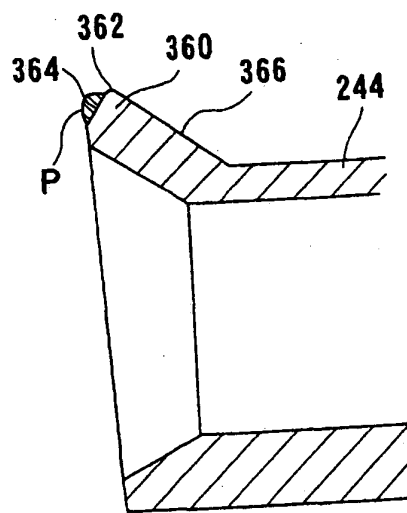
**FIG. 16A**



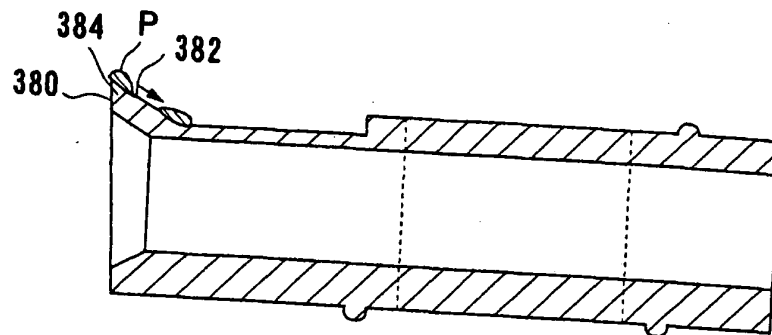
**FIG. 16B**



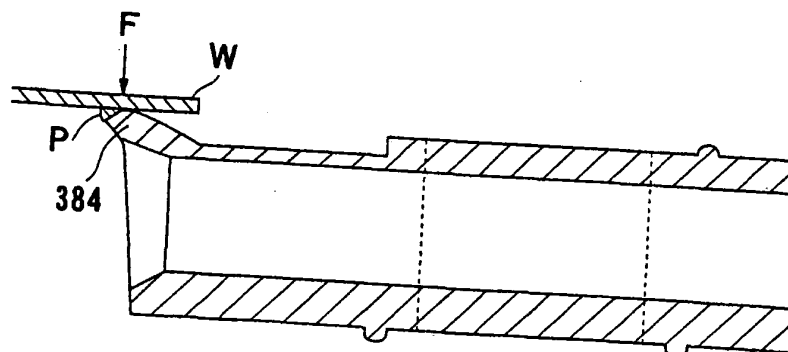
**FIG. 16C**



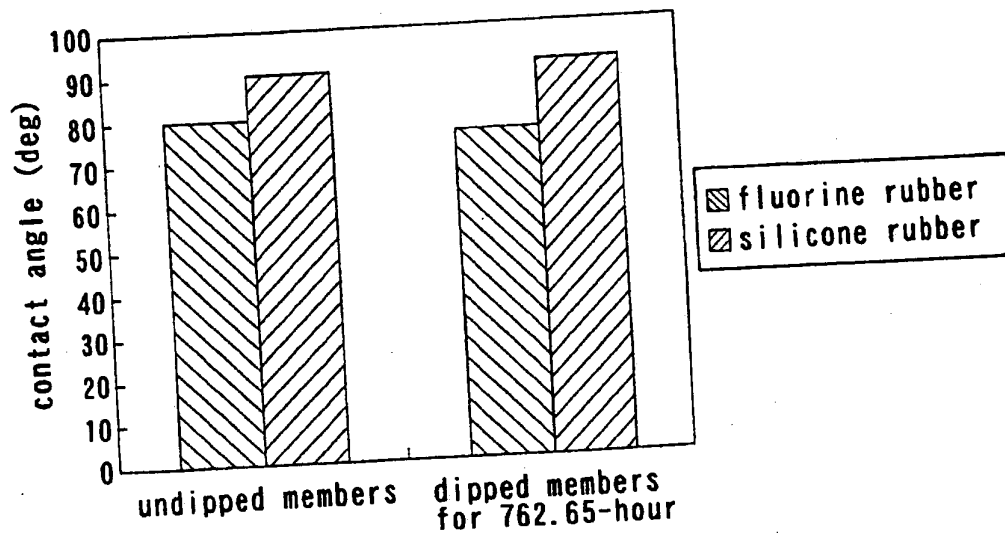
*FIG. 17A*



*FIG. 17B*



*FIG. 18*



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